Enabling Technology Transforms a Prototype GNSS Interferometric Reflectometry (GNSS-IR) System to Global Operation

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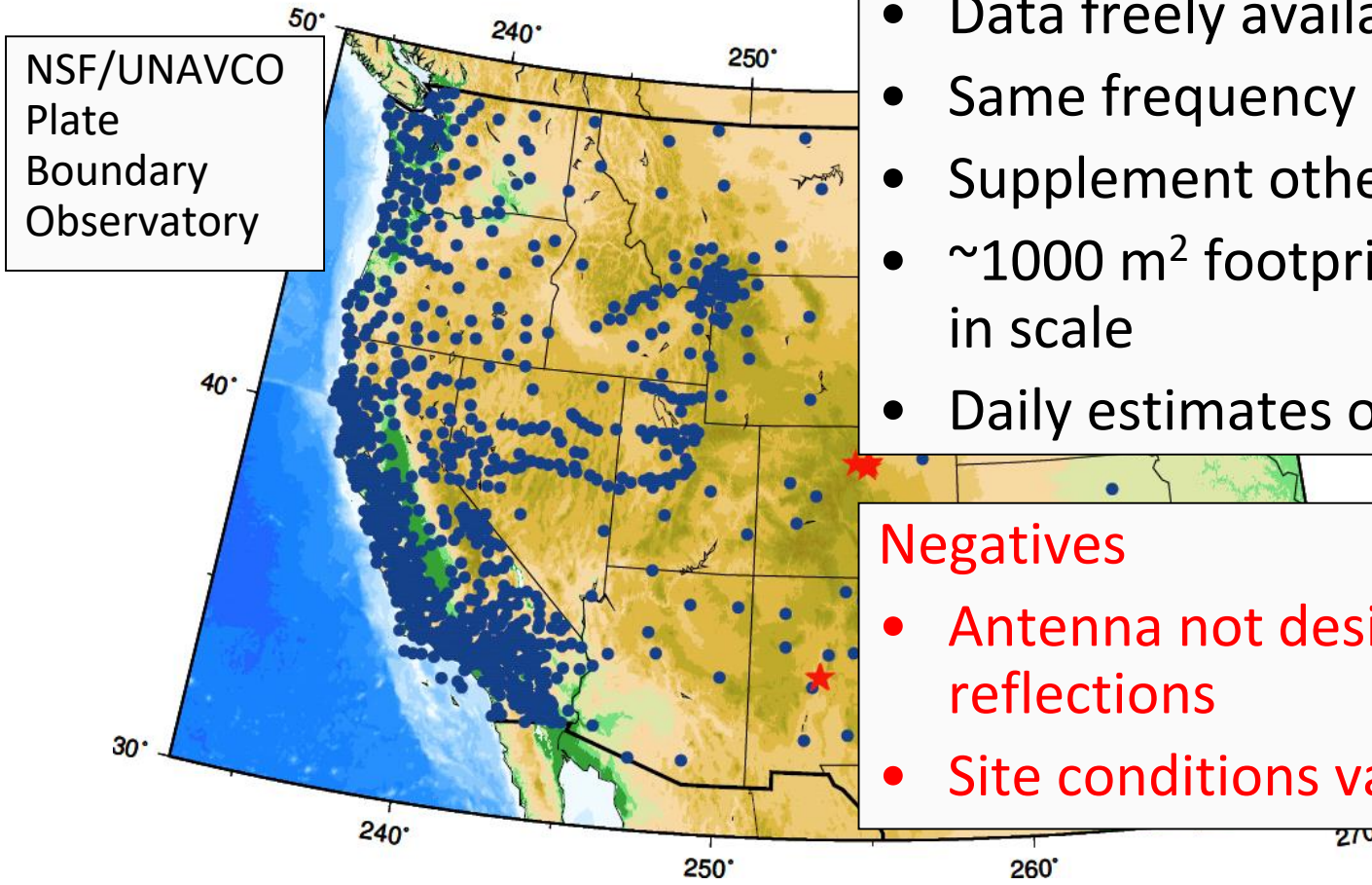
Outline

- GNSS Interferometric Reflectometry (GNSS-IR)
- Prototype system and challenges for globalization
- Automated evaluator of candidate site characteristics
- Automated site submission portal
- Framework for process management
- Architecture to enable cloud operations

Why use ground GPS to estimate hydrologic variables?

1. Snow Depth and SWE
2. Soil moisture
3. Vegetation Water Content

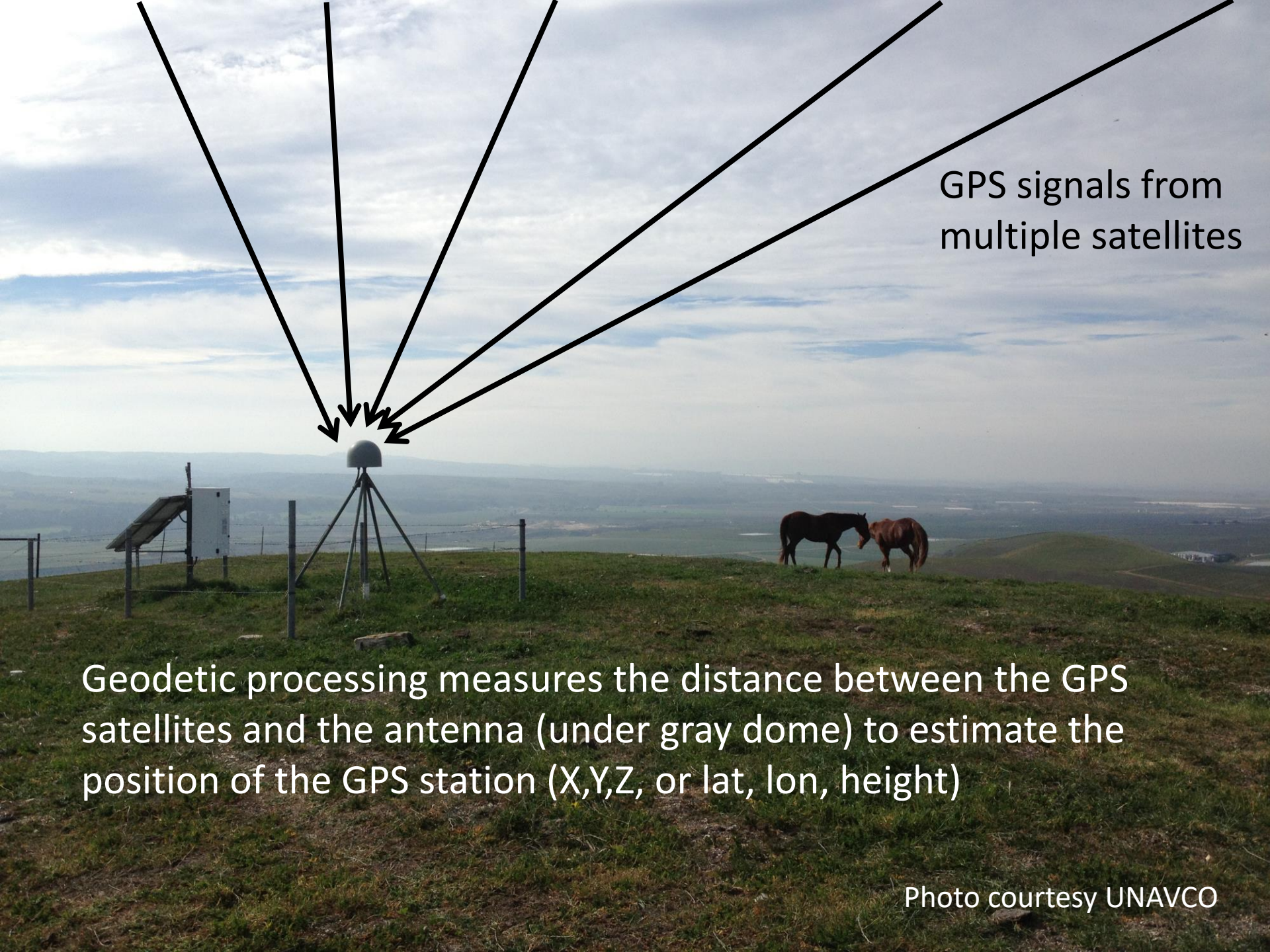


Advantages

- Extensive infrastructure exists
- Data freely available
- Same frequency as satellites
- Supplement other *in situ* sensors
- ~1000 m^2 footprint intermediate in scale
- Daily estimates or better

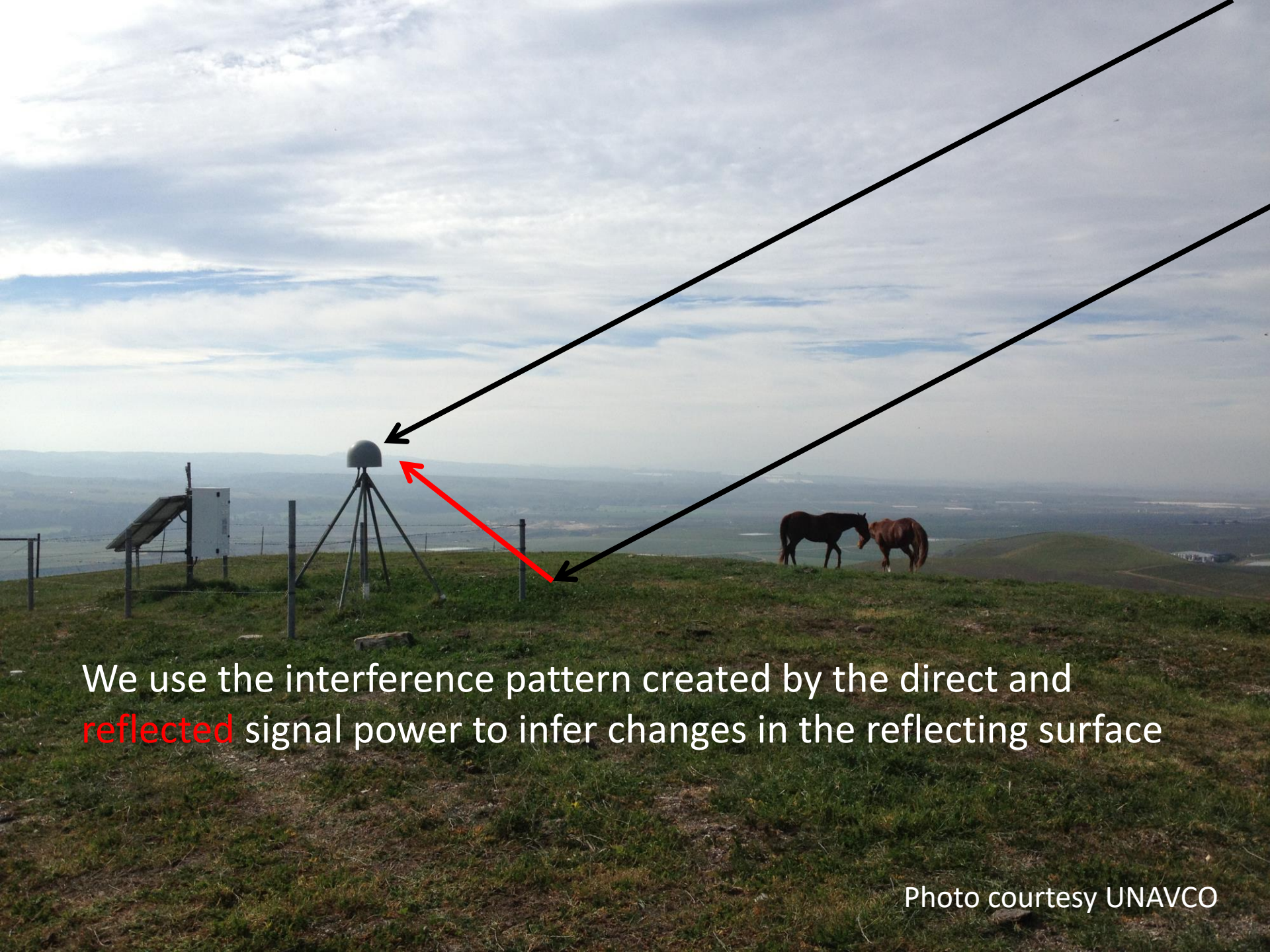
Negatives

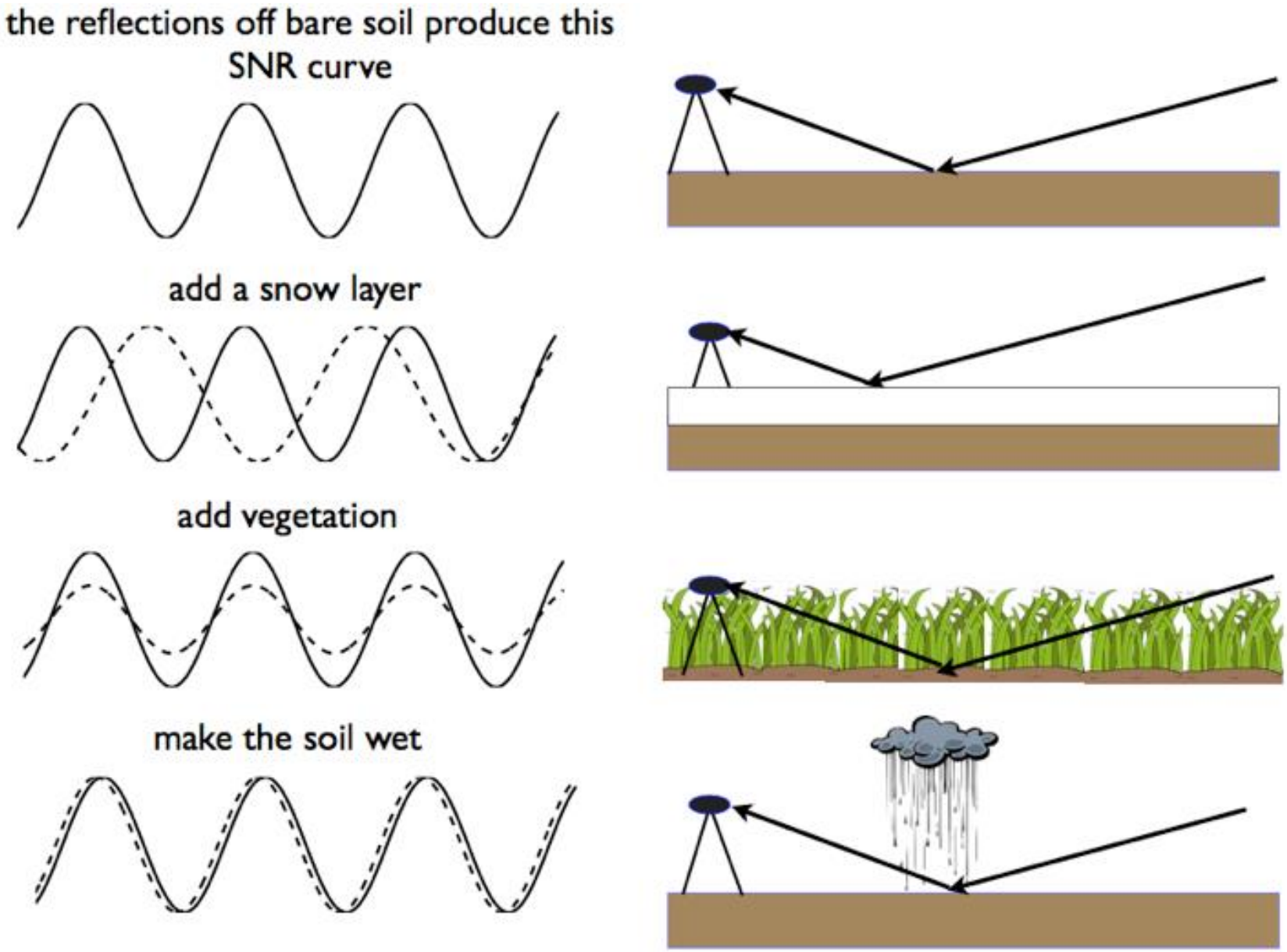
- Antenna not designed for reflections
- Site conditions vary



Geodetic processing measures the distance between the GPS satellites and the antenna (under gray dome) to estimate the position of the GPS station (X,Y,Z, or lat, lon, height)

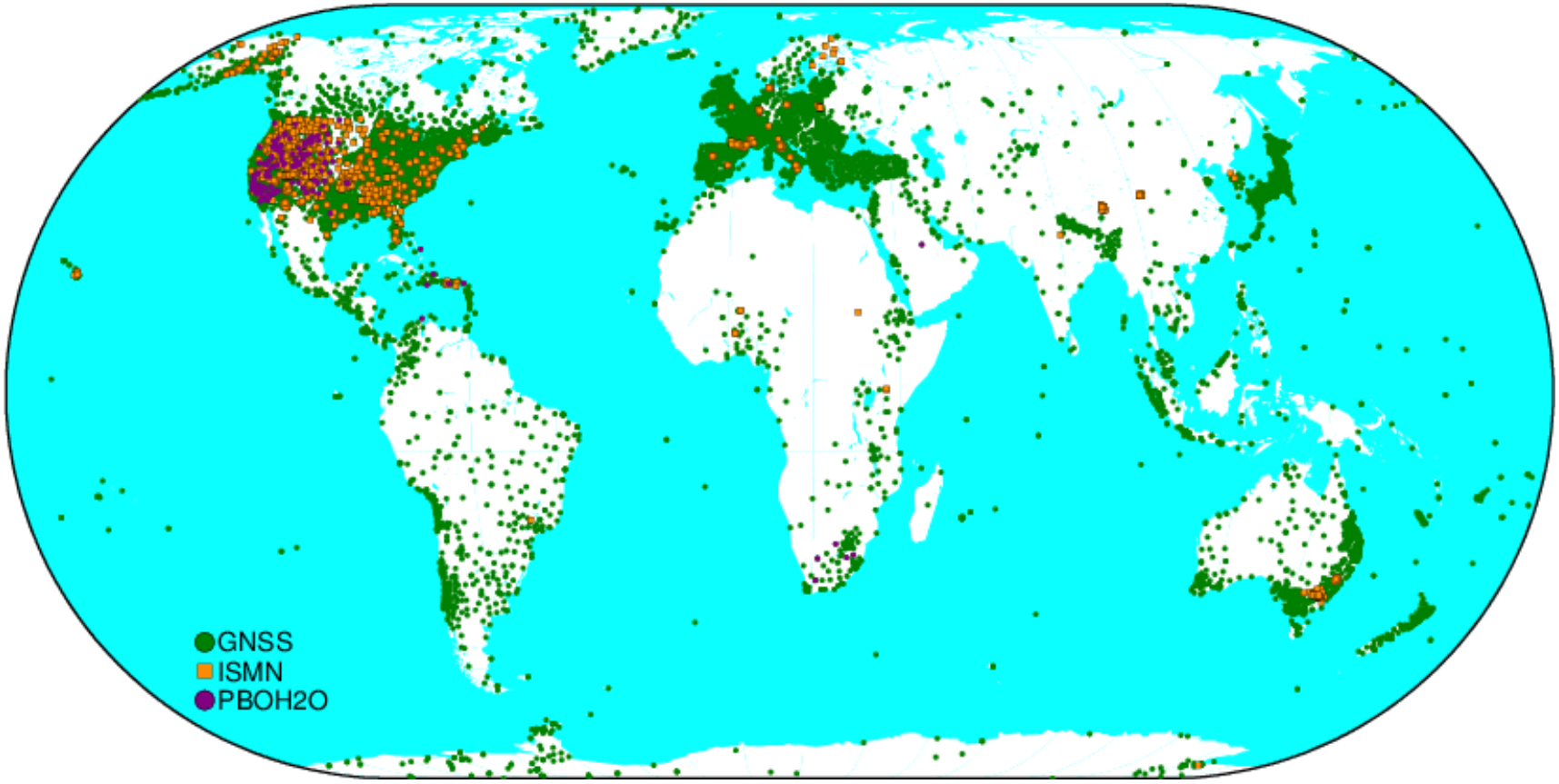
Photo courtesy UNAVCO


We use the interference pattern created by the direct and
reflected signal power to infer changes in the reflecting surface
Photo courtesy UNAVCO



Larson et al., 2008 (GRL) ; Larson et al., 2009 (GRL); Larson and Small, 2014 (JSTARS)

From Regional to Global



International Soil Moisture Network

Public GNSS sites

PBO H2O pilot project

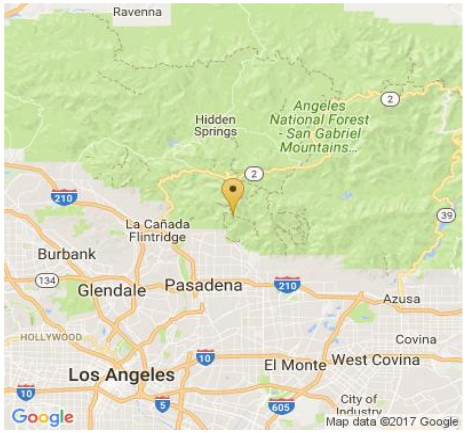
The PBO-H_2O prototype was purpose-built for the largely homogenous PBO network, but there are many more subnetworks available.

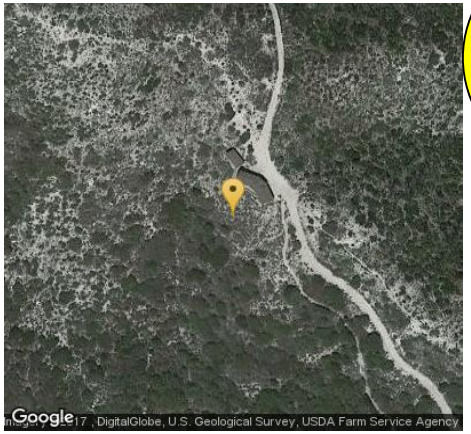
Station Evaluator – site characteristics

Software searches online sources and produces a human-readable report, or machine-readable JSON output.

Evaluation of site INSP 34.221391 -118.109486

0. Local area map and aerial image (not same scale)





Given a location…

the tool provides a location map and aerial imagery from Google Maps…

Station Evaluator – site characteristics

1. Evaluation of buildings and roads in +/- 50m square per OpenStreetMap

```
found way:
  sac_scale hiking
  name Castle Canyon Trail
  highway path
 Range: 23 - 242 meters
 Bearings: ['68', '99', '124', '134-135', '141', '143', '147', '149-150', '166', '171', '173', '183',
 Quadrants: ['1', '3', '4']

found way:
  highway track
 Range: 27 - 220 meters
 Bearings: ['68', '116', '124', '126', '132', '135-136', '138']
 Quadrants: ['1', '4']

found way:
  building yes
  name Inspiration Point Paviillion
 Range: 17 - 23 meters
 Bearings: ['13', '15', '33-34', '47-48', '67-68']
 Quadrants: ['1']

found way:
  building yes
  name Inspiration Point Picnic Paviillion
 Range: 23 - 31 meters
 Bearings: ['4', '10', '16', '358']
 Quadrants: ['1', '2']

found way:
  sac_scale hiking
  name Fire Road
  highway track
 Range: 27 - 230 meters
 Bearings: ['2', '4', '6', '11', '16', '25', '39', '68', '336-338', '342', '346-347', '349', '354']
 Quadrants: ['1', '2']

found way:
 Range: 38 - 230 meters
 Bearings: ['47', '129', '346']
 Quadrants: ['1', '2', '4']

 Location: United States of America; California; Los Angeles County;
```

… nearby buildings and roads per OpenStreetMap…

2. Evaluation of Landcover per MODIS MCD12Q1

```
8: Woody Savannas
```

Landcover types within 1km square:

```
7: Open shrublands
8: Woody Savannas
9: Savannas
12: Croplands
```

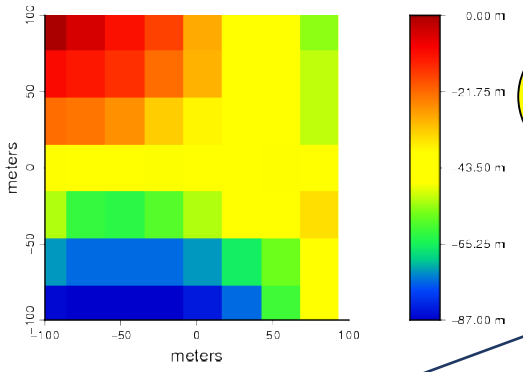
… landcover types per MODIS …

Station Evaluator – site characteristics

Station Evaluator is available for licensing from JPL/Caltech.

3. Evaluation of DEM per OpenTopography SRTM GL1 (30m)

DEM reports elevation 1366.68129022 m
87.0 meters of relief in a +/- 100m square
51.08 meters of relief in a +/- 50m square



… a DEM and amount of relief per SRTM and OpenTopography …

… references for the sources searched…

References:

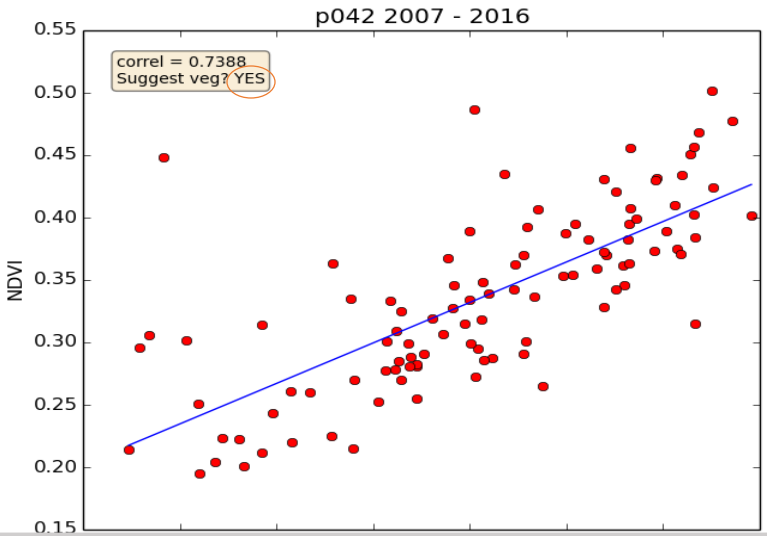
- (c) OpenStreetMap contributors. Data available under Open Database License.
- ORNL DAAC 2017. MODIS Collection 6 Land Products Global Subsetting and Visualization Tool. ORNL DAAC, Oak Ridge, Tennessee, USA. Accessed 2017-04-13. Subset obtained for MCD12Q1 product at 34.2214,-118.1095, time period 2001001-2002001, and subset size: 1X1km
- This material is based on data services provided by the OpenTopography Facility with support from the National Science Foundation under NSF Award Numbers 1226353 & 1225810

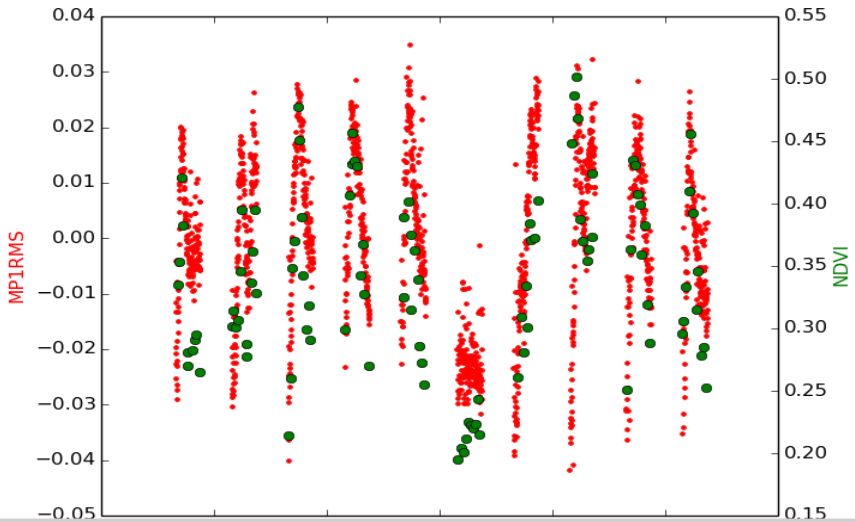
Appendix: JSON output

{"100m_relief_m": "87.0", "50m_relief_m": "51.08", "elev_m": "1366.68129022", "generator": "eval_characteristics.py", "landcover": {"IGBP_type": "8.0", "name": "Woody Savannas"}, "landcover_1km": [{"IGBP type": "7", "name": "Open shrublands"}, {"IGBP type": "8", "name": "Woody Savannas"}, {"IGBP type": "9", "name": "Savannas"}, {"IGBP type": "12", "name": "Croplands"}], "lat": "34.221391", "location": {"2": "United States of America", "4": "California", "6": "Los Angeles County"}, "lon": "-118.109486", "name": "INSP", "objects_50m": [{"quadrants": ["1", "3", "4"], "range_m": "23", "tags": [{"sac_scale": "hiking"}, {"name": "Castle Canyon Trail"}, {"highway": "path"}]}, {"quadrants": ["1", "4"], "range_m": "27", "tags": [{"name": "One Man & Mule Trail"}, {"highway": "track"}]}, {"quadrants": ["1"], "range_m": "17", "tags": [{"building": "yes"}, {"name": "Inspiration Point Paviillion"}]}, {"quadrants": ["1", "2"], "range_m": "23", "tags": [{"building": "yes"}, {"name": "Inspiration Point Picnic Paviillion"}]}, {"quadrants": ["1", "2"], "range_m": "27", "tags": [{"sac_scale": "hiking"}, {"name": "Fire Road"}, {"highway": "track"}]}, {"quadrants": ["1", "2", "4"], "range_m": "38", "tags": []}]}

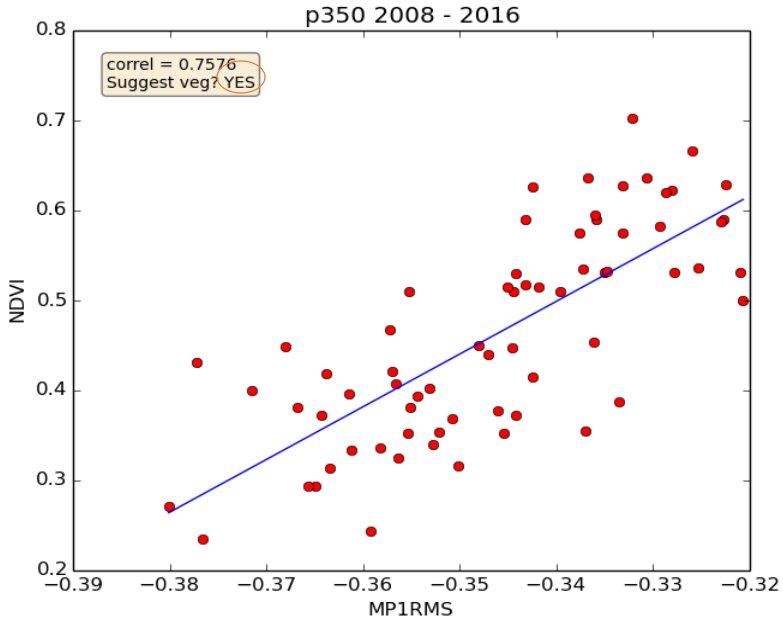
…and machine-readable JSON output.

Vegetation Evaluator Test

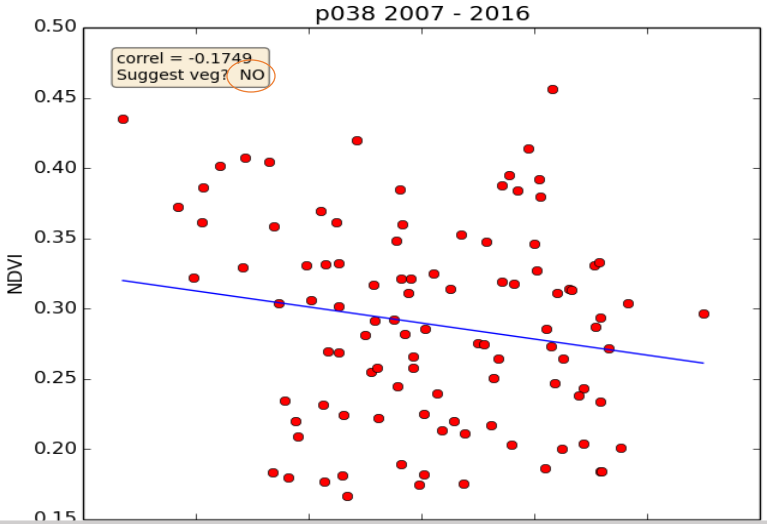


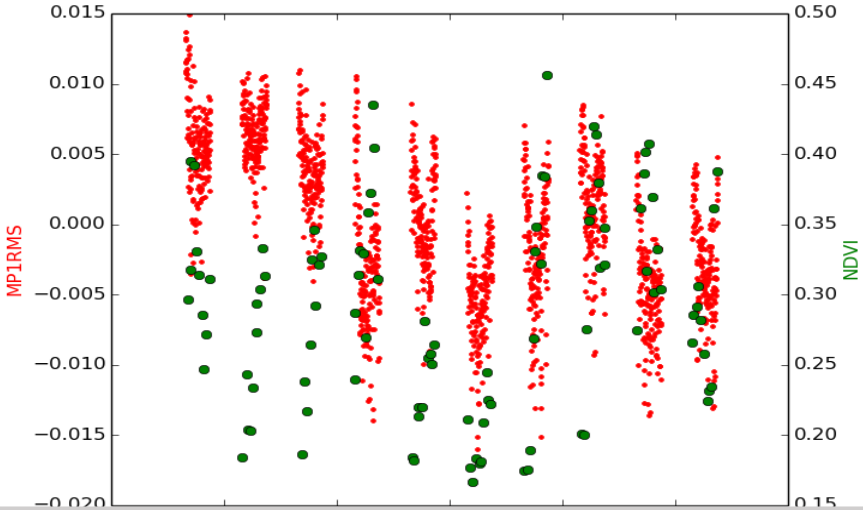


Evaluator recommends these, in agreement with a human

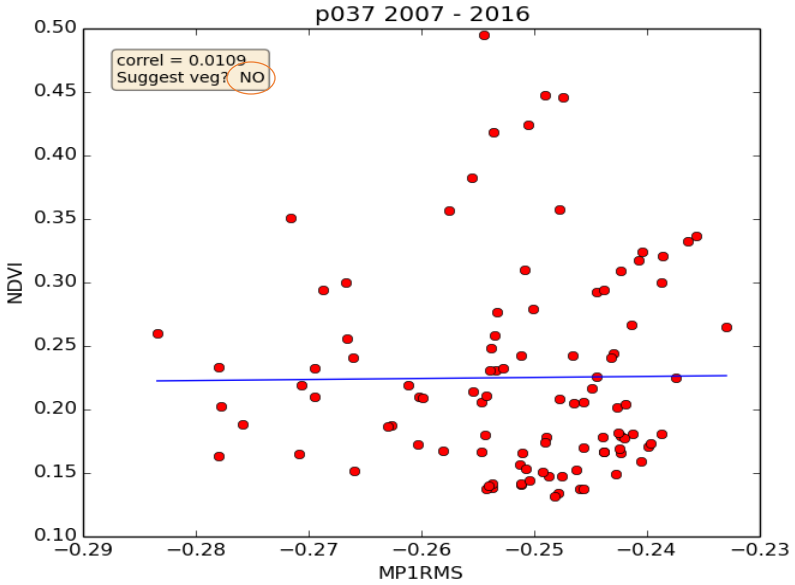


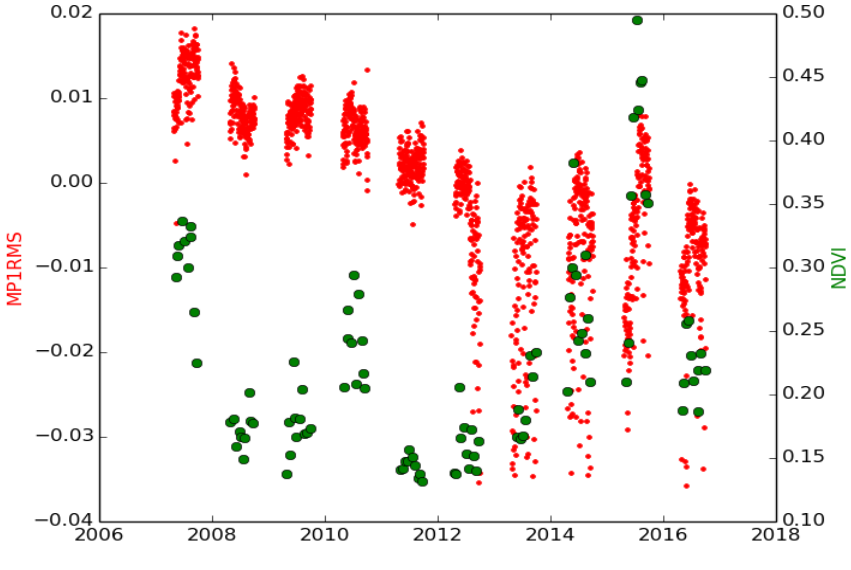
Vegetation Evaluator Test



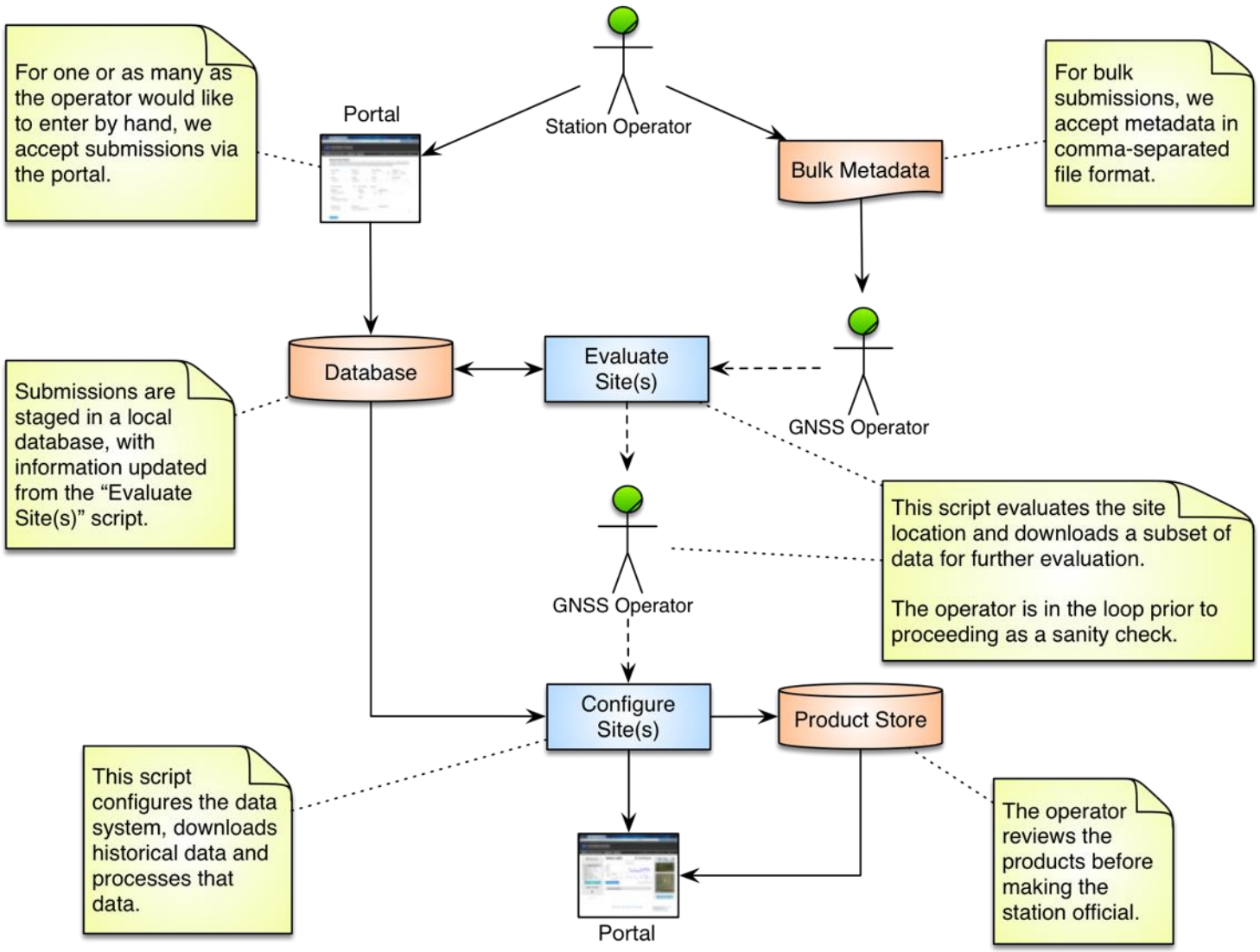


Evaluator recommends against these, which were also deselected by a human

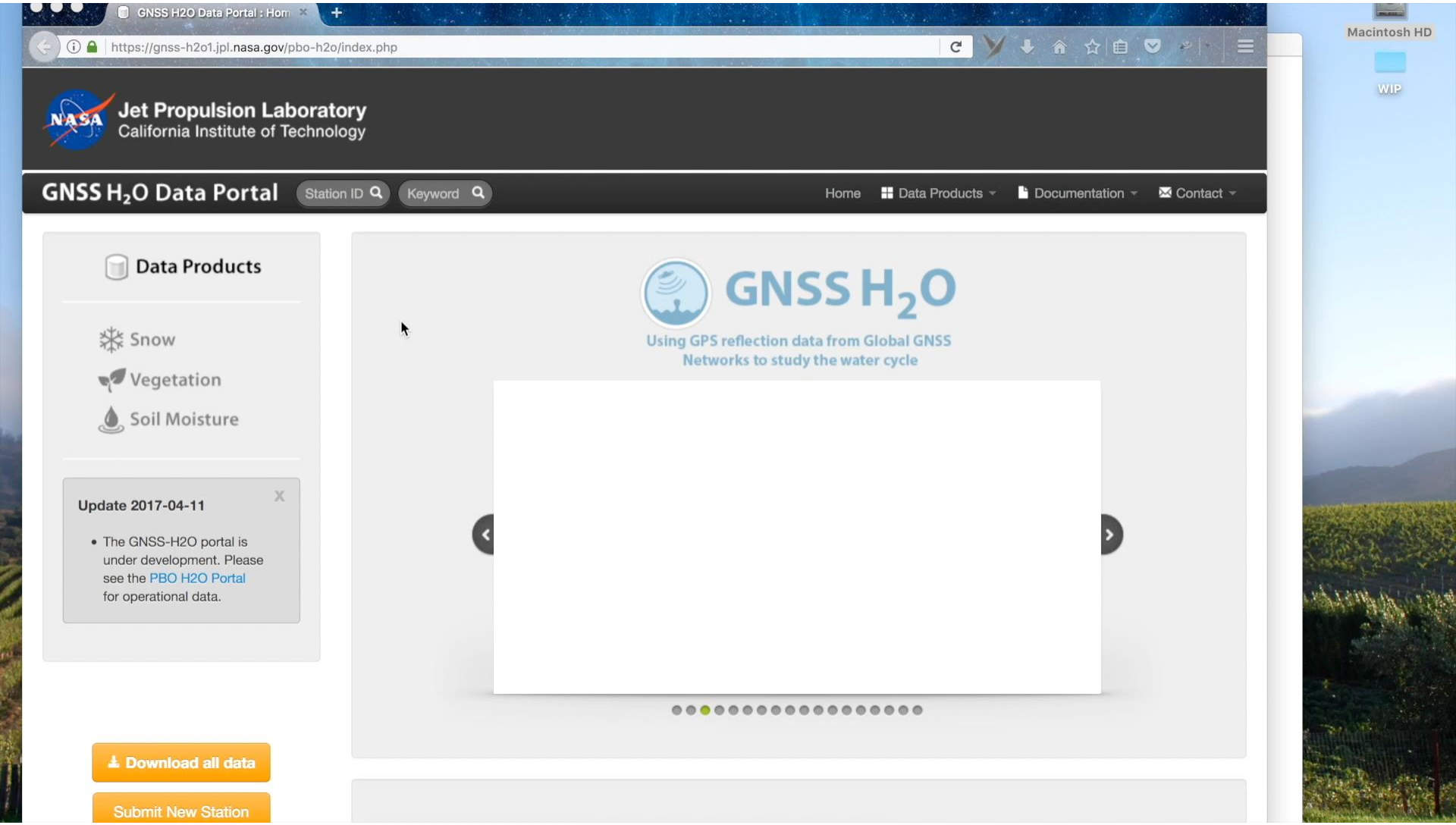




Demonstration of site submission automation



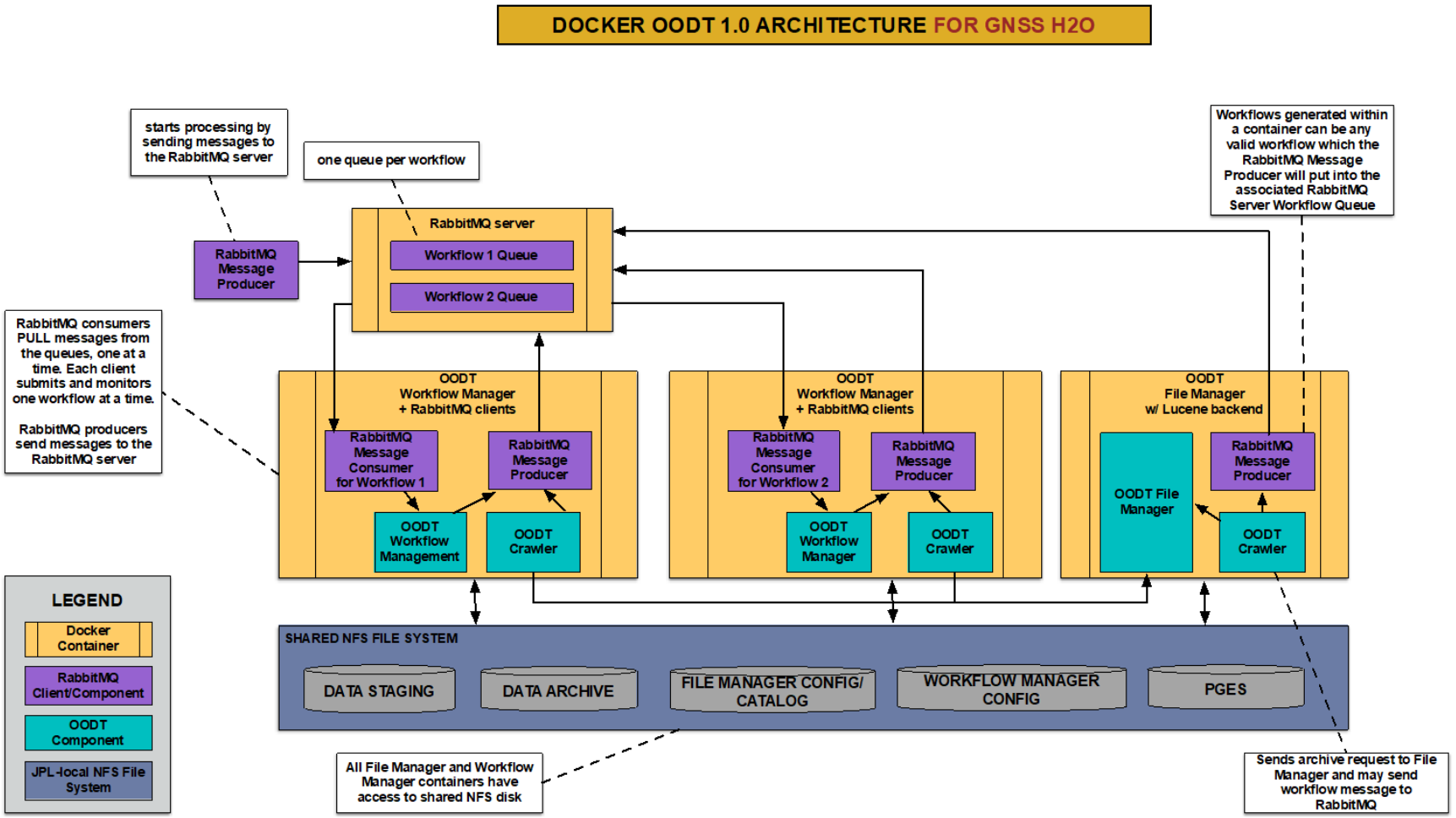
Demonstration of site submission automation



Containerization strategy

Deployable on any platform (cluster, cloud, hybrid cloud, laptop…)

Code was refactored into Apache OODT, an adaptable framework for ingestion, management, processing, and distribution of science data



Summary

- GNSS-IR measures snow, soil moisture, and vegetation fluctuations over an area ~1000 m^2
- A prototype western-U.S. system is currently available (http://gnss-h2o.jpl.nasa.gov)
- Technology to enable globalizing the project has been developed
  - Automated evaluator of site physical and data characteristics
  - Portal for submission of candidate new sites
  - OODT framework for process management
  - Containerized architecture permits cloud operations

Thank you: NSF, UNAVCO, NASA